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Immediate effects of voice focus adjustments on hypernasal speakers' nasalance scores

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ABSTRACT

Objectives: To explore the immediate effects of voice focus adjustments on the oral-nasal balance of hypernasal speakers, measured with nasalance scores.
Methods: Five hypernasal speakers (2 M, 3 F) aged 5–12 (SD 2.7) learned to speak with extreme forward and backward voice focus. Speakers repeated oral, nasal, and phonetically balanced stimuli. Nasalance scores were collected with the Nasometer 6450.
Results: From the average baseline of 34.27% for the oral stimulus, nasalance increased to 46.07% in forward and decreased to 30.2% in backward focus. From the average baseline of 64.53% for the nasal stimulus, nasalance decreased to 64.13% in forward and decreased to 51.73% in backward focus. From the average baseline of 51.33% for the phonetically balanced stimulus, nasalance increased to 58.87% in forward and decreased to 46.2% in backward focus.
Conclusions: Forward voice focus resulted in higher and backward voice focus resulted in lower nasalance scores during speech for a group of hypernasal speakers. However, there was an exception: One male speaker showed decreased nasalance in forward voice focus. Future research should investigate the longer-term effectiveness of the intervention.

1. Introduction

Oral-nasal balance is an attribute of voice quality describing the division of sound between the oral and nasal cavities. It is primarily controlled by a valving mechanism, i.e., the velopharyngeal sphincter, and normal speech depends on its proper functioning. When there is inadequate separation between the oral and nasal cavities, this results in irregular sound transmission through the nose [1]. Hypernasality occurs when the velopharyngeal sphincter cannot adduct completely. This causes excessive sound to escape into the nasal cavity, resulting in the nasalization of voiced speech sounds. Hypernasal speech can impact intelligibility and negatively affect social interaction [2–5], sometimes resulting in psychosocial problems such as anxiety, depression and low self-esteem [6].

A craniofacial condition often characterized by the symptom of hypernasal speech is cleft palate [7]. Even after surgery to repair the cleft, patients may still exhibit velopharyngeal insufficiency [8,9]. Other reasons for hypernasal speech include non-cleft related velopharyngeal insufficiency caused by mechanical interference (e.g., short velum, large tonsils or adenoids), or surgical ablations related to cancer. Hypernasality can also be symptomatic of velopharyngeal incompetence caused by a neurogenic speech disorder (e.g. dysarthria or apraxia) [1].

A commonly used assessment tool for the quantification of oral-nasal balance is the Nasometer 6450 (Pentax Medical, Montvale, NJ). The Nasometer includes a headset with two directional microphones on either side of a metal sound separator plate, which is placed on the speaker's upper lip halfway between the nose and the mouth. The device provides an acoustic measure of nasality by quantifying the amount of acoustic energy emitted from the nose, calculated as the proportion of nasal to oral sound pressure level (SPL). It is reported as a percentage, based on the formula: nasalance (%) = nasal SPL/(nasal SPL + oral SPL) x 100. The higher the nasalance score, the more nasal sound pressure is present in the speech signal [10,11].

Successful rehabilitation of velopharyngeal movement requires both adequate structure and function. When hypernasality is the result of a structural or neurological deficit, behavioural intervention is generally considered ineffective [1]. It is also difficult to influence

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velopharyngeal movement with speech therapy because the velopharyngeal sphincter offers only minimal conscious proprioception. This makes it difficult to attain volitional control of its movement [12]. Treatment with speech therapy to improve velopharyngeal closure for speech is therefore only recommended to a limited number of patients with mild to moderate hypernasality with a physically capable velopharyngeal closure mechanism [13]. Therapeutic techniques that have been suggested include pitch and loudness modification [14–18], perceptual training [19], cul-de-sac therapy with pinched nostrils [1,20], and articulatory drills [13,16,17,21,22].

While the velopharyngeal sphincter is the most important regulator of oral-nasal balance, the position and movement of the articulators in the vocal tract also has some influence. Speech research investigating vowel effects on oral-nasal balance has shown that sentences loaded with high front vowels (e.g./i/ and /I/) result in higher velar elevation and firmer velopharyngeal closure than sentences loaded with low backed vowels (e.g./o/ and /a/) [23–26]. Nasal sound pressure levels are higher for high vowels and front vowels [27,28]. When there is hypernasality, these vowels are perceived as more nasal [29]. This is also reflected in higher nasalance scores for high and front vowels [30–33]. The effect can probably be explained by the relative impedance of the oral and nasal cavities [34,35]. As the airspace in the oral cavity is constricted by the raised tongue, more acoustic energy is emitted from the nose. In a typical speaker, this can happen despite complete velopharyngeal closure because the soft palate has some degree of acoustic transparency [36,37].

Several authors have suggested that hypernasal speech can be reduced by reducing oral impedance and routing sound through the oral cavity via increased mouth opening, low tongue positioning and widening of the pharynx with a yawn-type maneuver [1,9,18,38–42]. Based on a computer simulation of the vowel /i/, Rong & Kuehn [43] further reported that expanding the pharynx and protruding the tongue body should reduce the perception of hypernasality.

These ideas appear similar to the shaping of voice focus in singing pedagogy. The concept of voice focus is rooted in the vocal ideal of *chiaroscuro*. *Chiaroscuro* has been taught with regularity since the Bel Canto age and refers to an optimum timbral mixture of light and dark tone. The quality is achieved by singing with a lowered larynx, raised velum, and a released forward tongue [44].

In speech-language pathology, Boone [45] defined a voice that was “in focus” as coming “… from the middle of the mouth, just above the surface of the tongue” (pp. 71), and further explained that voices that were excessively forward (raised larynx, protruded tongue, narrowed pharynx) or backward (lowered larynx, retracted tongue, widened pharynx), were considered “out of focus”. Excessive forward voice focus sounds bright, thin and juvenile, while excessive backward voice focus sounds dark and throaty [18].

Bressmann et al. [46] described how a forward voice focus resulted in reduced nasalance scores in a hypernasal speaker with a speech bulb prosthesis. This inspired de Boer and Bressmann [47] and de Boer et al. [48] to investigate the effect of forward and backward voice focus adjustments on the oral-nasal balance of typical speakers of Canadian English and Brazilian Portuguese. Santoni et al. [49] then investigated the effect of extreme voice focus (as forward and as backward as possible) on the oral-nasal balance of normal speakers in speech and singing. All three studies demonstrated that speaking (and singing) in a forward focus increased nasalization, whereas speaking (and singing) in a backward focus reduced nasalization, as demonstrated by nasalance scores. Intriguingly, one participant in Santoni et al. [49] produced markedly lower nasalance scores when speaking in the forward voice focus condition.

Velopharyngeal closure in speech and swallowing is task-dynamic [50,51], and velopharyngeal closure has been reported as tighter in singing compared to speech, particularly during pitch ascent [52,53]. Research has also shown that singers adjust velopharyngeal port closure configuration based on timbral preference and singing style [54–56]. Tanner et al. [57] demonstrated that some trained sopranos may show small velopharyngeal leaks during singing. On the other hand, classical singers have been shown to produce lower nasalance scores during sustained vowel production compared to amateurs [58]. To date, the only clinical study investigating the effect of a singing task on hypernasality was completed by Peter, Abdul Rahman and Pillai [59]. The authors recruited twenty children who had cleft palate, aged 7–12 years old and had them produce a speech task in Malaysian (the Kampung Passage), and sing a common Malaysian song loaded with oral and nasal sounds. Perceptual assessments using a visual analogue rating scale indicated a significant reduction in hypernasality during the singing versus the speech task. However, it was unclear whether the phonetic content of the speech and singing tasks were comparable.

Since previous studies described the effects of voice focus adjustments in typical speakers [47–49] as well as in a single hypernasal speaker [46], the present pilot study investigated the effect of forward and backward voice focus adjustments on nasalance scores in a small group of hypernasal speakers. The study aimed to explore the following hypotheses, based on the research results from typical speakers [47–49]:

H1: Forward voice focus will result in higher nasalance scores.

H2: Backward voice focus will result in lower nasalance scores.

Similar to previous work [49], the study also included a song. This was motivated by the observation by Bell-Berti and Krakow [60] that longer vowel durations reduce the co-articulatory impact of adjacent consonants on velopharyngeal closure (i.e., the velum is in a stable closed position for longer). The song was included in order to explore whether the longer vowel durations in a singing task would increase the impact of the voice focus adjustments on oral-nasal balance compared to the speech tasks.

2. Methods

2.1. Participants

Study participants were recruited from the Palato-Facial Management Clinic at Five Counties Children's Centre in Peterborough, Ontario. A referring speech language pathologist circulated the research study recruitment flyer to eligible participants with hypernasal speech (with or without a diagnosis of cleft palate) in the speech clinic's caseload. The flyer described the study purpose as an investigation of the regulation of oral-nasal balance in speech and singing using voice focus. The administration at the Five Counties Children's Centre and the Office of Research Ethics at the University of Toronto approved the study.

Seven children (3 M, 4 F), ranging in age from 5 to 12 years old, with a mean age of 7.86 (SD 2.91), served as the participants for this study. All of the participants were screened for hypernasality and identified as eligible (i.e., their speech was hypernasal) for the study by their speech language pathologist. Participants had normal hearing as reported by the speech-language pathologists who referred them to the study. All of the subjects spoke Canadian English with the accent typical to Southern Ontario.

Individual participant background information can be viewed in Table 1. Three speakers had repaired hard and soft cleft palate, and of these, one had an associated diagnosis of Pierre Robin Sequence. Two speakers had 22q11 Deletion Syndrome with no manifest clefts, and two speakers presented with velopharyngeal dysfunction absent of a diagnosis.

2.2. Materials

The stimuli used in this study were similar to what was used in previous research [49]. Speech materials included two oral sentences from the Zoo Passage (“Look at this book with us. It's a story about a zoo”) [10], the nasal sentence: “Mama made some lemon jam”) [10],

Table 1
Participant information.

Participant Information				
Speaker	Gender	Age	Speech Observations	Medical History
1	F	12	History of mixed nasality, but predominantly mildly hypernasal. Dysphonic, hypotonic.	No known cleft, query submucous cleft and VPI. 22q11.
2	F	6	Resonance that ranges from acceptable to mild hypernasal with occasional nasal turbulence. Speech production delay.	Repaired hard & soft palate cleft, secondary repair: posterior pharyngeal flap.
3	F	7	Moderate-severe hypernasal with frequent nasal turbulence. Speech production delay.	Repaired hard & soft palate cleft, short palate length. Pierre Robin Sequence.
4	M	5	Hypernasal. Severe motor speech issues (query apraxia).	No known cleft or syndrome, query VPI.
5	F	6	Acceptable resonance, history of fluctuating to mildly hypernasal. Quiet voice, weak projection, high pitch.	No known cleft. Low facial tone, open mouth posture at rest. 22q11.
6	M	12	Acceptable to mild hypernasality with audible nasal turbulence. Delayed articulation/speech sound production.	Repaired hard and soft palate cleft.
7	M	7	Hypernasal, which increased after profound car accident and head trauma. Delayed articulation/speech sound production, and motor speech.	No known cleft, query VPI or motor coordination difficulties impacting VP function.

and a phonetically balanced sentence from the beginning of the Rainbow Passage ("When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow") [61]. The song entitled the "Hamper Song"; used in previous research [62], was reduced to 4 bars. The song text contained both oral and nasal phonemes and read "My hamper was damp, so the towels are smelly". Written in 3/4 time, it was composed in B-flat Major with a pitch range of F3-D4 (i.e. 174.6–293.7 Hz). This is an appropriate frequency range for children aged 6–10 years [63], which was also considered reasonable for the participants aged 5–12 years in the present study. An instrumental introduction made up of two broken triads was played before the melody designed to cue the beginning of the song.

Documented normative mean scores for the chosen speech stimuli have been reported as 11.25% for the Zoo passage, 59.55% for the nasal Jam sentence, and 31.47% for the Rainbow passage [64]. Based upon prior research on normal participants [49], the mean score for the "Hamper Song" was 33.35%. For an oral speech stimulus like the Zoo Passage, scores below 28% indicate no hypernasality, scores between 28 and 40% indicate a mild degree of hypernasality and scores over 40% denote considerable hypernasality [1,65,66].

2.3. Participant training

Each of the participants had the opportunity to practice the stimuli prior to the experiment. For the speech stimuli, the 12-year-old children (n = 2) read through all of the materials on their own. For the children that were 5–7 years of age (n = 5), the first author practiced all stimuli with the children to make sure that the nasalance scores were not affected by reading errors For the song, the first author sang the tune to all the participants several times to orient them to the melody. Participants were then given the opportunity to rehearse the song with the instrumental accompaniment track several times prior to commencement of the experiment. Participants were asked to produce all stimuli in a *mezzo-forte* (medium-loud) voice.

The voice focus training protocol was based on previous work [47,48] and had been formalized into a set protocol [49]. The first author (a trained classical singer and experienced post-secondary studio voice instructor) demonstrated the voice focus maneuvers to each of the participants. During each voice focus posture, participants were encouraged to take note of the associated perceptual and sensory qualities specific to each condition. Once the first author decided that the target voice was produced consistently, recordings of the stimuli were made. If the target voice was lost during the recordings, the participants were asked to stop, and teaching resumed.

Instruction for backward voice focus combined the following facilitating techniques: Opening the mouth wide, yawning, tactile laryngeal awareness, as well as unison production with, and mirroring of, the experimenter. Prior to the procedure, study participants were told: "We will place the voice downward and back, creating a large hollow space for our voice to resonate in". Participants were asked to open their mouth wide and inhale on the gesture of a yawn in order to orient them to maximal laryngeal lowering. In order to maintain the low-positioned larynx, maintenance of the inhalatory yawn gesture (as if speaking through a stifled yawn-sigh) using a dark, throaty "operatic" voice permeated the procedure. Participants were encouraged to say /a/ several times to practice and maintain the vocal tract posture.

Instruction for forward voice focus combined the following facilitating techniques: Spreading the lips, swallowing, tactile laryngeal awareness, as well as unison production with, and mirroring of, the experimenter. Prior to the procedure, study participants were told: "We will place the voice forward and up creating a small constricted space for our voice to resonate above our larynx". Participants were asked to spread their lips wide and swallow in order to orient them to maximal laryngeal elevation. They were encouraged to keep the larynx at the high point of their swallow in order to produce a flat and bright "cartoon" voice. Participants were further encouraged to say /i/ on an ascending glissando repeatedly using the "cartoon" voice to practice and maintain the vocal tract posture.

Four participants (2 M, 2 F) learned the forward voice focus condition first and the backward voice focus second, while the other three participants (1 M, 2 F) learned the maneuvers in the opposite order.

2.4. Recording procedures

Recordings took place in a quiet room, and the Nasometer 6450 (Pentax Medical, Montvale, NJ) was used to record all participants. The nasometer was calibrated once in the morning and once in the afternoon on each recording day. Recordings were saved on a hard disk and measured after the experiment was over. Recordings of the stimuli were always made in the following order: Oral stimulus, nasal stimulus, phonetically balanced stimulus, and song. The speech stimuli were repeated three times and the song was sung only once. In order to effectively execute the singing task, participants sang along to an accompaniment track wherein the melody was played with a flute sound through one headphone speaker (SHL3000RD, Philips Canada, Markham, ON) placed over their left ear. The track was played back from a computer tablet (Stream 7 Tablet, Hewlett-Packard Canada, Mississauga, ON). Nasalance scores were obtained during production of all of the stimuli at four time points: baseline 1, voice focus condition 1, voice focus condition 2, and baseline 2.

2.5. Data analysis

Statistical analyses were conducted using The Number Cruncher Statistical Software version 8.0 (NCSS, Kaysville, UT). Mean nasalance scores were used to characterize changes to individual participants' oral-nasal balance. An ad-hoc threshold of ± 10% from a participant's first baseline score was set as a benchmark for meaningful change in oral-nasal balance. The ± 10% cut-off score was chosen because it exceeded the typical test-retest nasalance score variability reported for normal and hypernasal speakers [31,67–71].

Inferential statistics were also explored. A repeated-measures analyses of variance (ANOVA) was run to compare the four recording conditions (baseline 1, forward voice focus, backward voice focus and baseline 2) on the nasalance scores of the averages of three repetitions of each of the speech stimuli. Speaking condition and stimuli were the within-subjects variables. Due to the substantial heterogeneity of the study group, no between-subjects variables (such as gender and order of intervention) were explored. Fisher's LSD Multiple-Comparison tests were utilized for further post-hoc analyses.

3. Results

For all of the participants, individual scores for all of the stimuli in the four voice focus conditions (baseline 1, forward, backward and baseline 2), as well as differences compared to baseline 1 can be found in Table 2.

Based on visual inspection of the nasalance data for the oral stimulus, it was found that two of the speakers had nasalance scores in the normal range. The baseline nasalance score for participant 2 was 13%, while the score for participant 6 was 18.33%, well below the cut-off score of 28% suggested by Dalston, Neiman and Gonzalez-Landa [65]. Therefore, participants 2 and 6 were not included in the descriptive and inferential analysis of the results. However, their data are reported in Table 2. Participant 7 did not wish to perform the song, so this stimulus was left out of the descriptive and inferential analyses due to the missing data.

The remaining five participants (participants 1, 3, 4, 5 and 7) (2 M/3 F) ranged in age from 5 to 12 years old, with a mean age of 7.4 (SD 2.7). All of these participants produced baseline nasalance scores between 27 and 40% during production of the oral stimulus. While participant 5 produced a score of exactly 27%, this subject was deemed appropriate for inclusion in the analysis due to the fact that their score was so close to the hypernasal threshold value of 28% [65]. This decision was also based upon examination of their elevated baseline scores across the other speech stimuli.

The mean scores for all of the speech stimuli in the four voice focus conditions (baseline 1, forward, backward and baseline 2), as well as differences compared to baseline 1 are reported in Table 3 and visualized in Fig. 1. The song was excluded from the descriptive analyses because of the missing data from participant 7.

From the average baseline of 34.27% (SD 6.1) for the oral stimulus, nasalance scores increased to 46.07% (SD 7.94) in the forward and decreased to 30.2% (SD 7.67) in the backward focus condition (largest individual differences for participant 1: +12%, participant 3 + 17% and participant 5: +25% for forward focus, and participant 4: 10% for backward focus).

From the average baseline of 64.53% (SD 4.45) for the nasal stimulus, nasalance scores decreased to 64.13% (SD 13.39) in the forward and decreased to 51.73% (SD 13.67) in the backward focus condition (largest individual differences for participant 3: +13% and participant 4: 22% for forward focus, and participant 4: 28% and participant 7: 32% for backward focus).

From the average baseline of 51.33% (SD 5.99) for the phonetically balanced stimulus, nasalance scores increased to 58.87% (SD 9.54) in the forward and decreased to 46.2% (SD 8.69) in the backward focus condition (largest individual differences for participant 3: +14% for

Table 2
Individual nasalance scores (%) and absolute differences for all of the stimuli in the four voice focus conditions (baseline 1, forward, backward and baseline 2) (N = 7, n = 6).

All speakers (N = 7, n = 6)							
Stimuli	Baseline 1	Forward	Backward	Baseline 2	Diff (B1-Fw)	Diff (B1-Bw)	Diff (B1–B2)
Oral Stimulus (N = 7)							
1	30	42	31	20	12	2	−10
2	13	22	15	12	9	2	−1
3	40	57	42	42	17	2	1
4	35	43	25	23	8	−10	−12
5	27	51	22	25	25	−5	−1
6	18	8	27	7	−11	8	−12
7	40	37	31	30	−3	−9	−10
Nasal Stimulus (N = 7)							
1	59	66	52	51	8	−7	−7
2	64	58	57	55	−6	−7	−9
3	65	79	67	65	13	2	0
4	65	43	37	45	−22	−28	−20
5	63	62	64	61	−1	1	−2
6	67	75	63	64	8	−4	−3
7	71	71	39	64	0	−32	−7
Phonetically Balanced Stimulus (N = 7)							
1	53	59	42	41	6	−11	−12
2	43	44	39	48	1	−5	4
3	57	71	60	54	14	3	−4
4	47	48	39	45	1	−8	−2
5	43	51	41	39	8	−2	−5
6	55	47	47	44	−8	−7	−11
7	56	65	49	67	9	−7	11
Song Stimulus (n = 6)							
1	48	63	38	44	15	−10	−4
2	28	58	17	29	30	−11	1
3	46	58	72	48	12	26	2
4	46	61	41	52	15	−5	6
5	37	55	32	37	18	−5	0
6	44	60	35	42	16	−9	−2

Table 3
Hypernasal group mean nasalance scores (%), standard deviations and absolute differences for the speech stimuli in the four voice focus conditions (baseline 1, forward, backward and baseline 2) (n = 5).

Hypernasal speakers (n = 5)							
Stimuli	Baseline 1	Forward	Backward	Baseline 2	Diff (B1-Fw)	Diff (B1-Bw)	Diff (B1–B2)
Oral Stimulus	34.27 (6.1)	46.07 (7.94)	30.2 (7.67)	27.93 (8.55)	12	−4	−6
Nasal Stimulus	64.53 (4.45)	64.13 (13.38)	51.73 (13.66)	57.4 (8.84)	0	−13	−7
Phonetically Balanced Stimulus	51.33 (5.99)	58.87 (9.54)	46.2 (8.69)	49.07 (11.35)	8	−5	−2
Mean	50.04 (13.82)	56.36 (12.52)	42.71 (13.45)	44.8 (15.65)	6	−7	−5

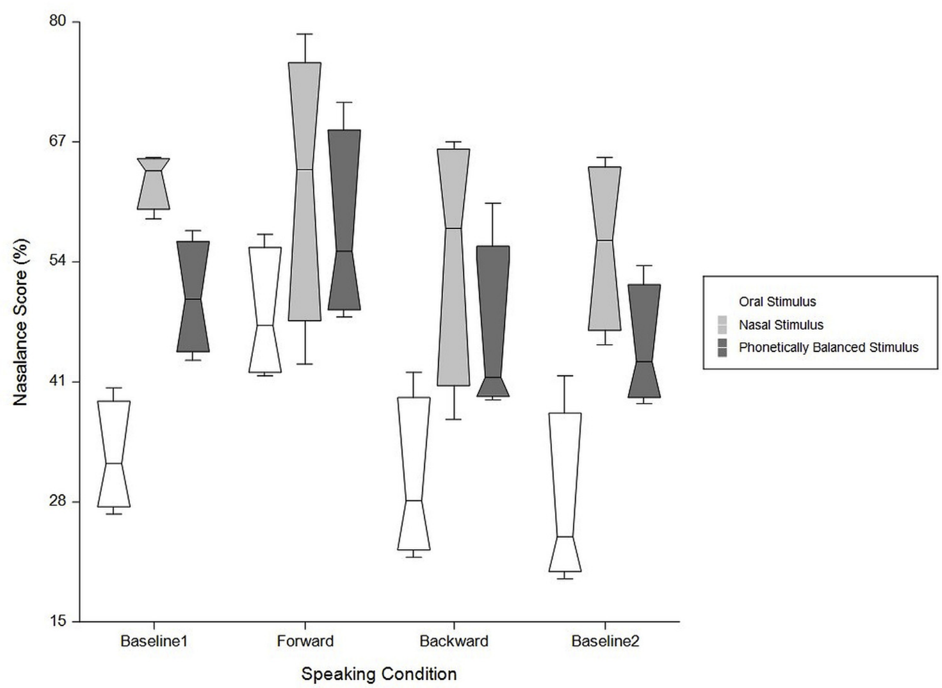

Fig. 1. Boxplots of the five hypernasal speakers' mean nasalance scores (%) for the speech stimuli in the four voice focus conditions (baseline 1, forward, backward and baseline 2) (n = 5).

forward focus, and participant 1: 11% for backward focus).

A repeated measures ANOVA was run on the data of the hypernasal patients (participants 1, 3, 4, 5 and 7) to evaluate the effects of the four voice focus conditions (baseline 1, forward, backward and baseline 2) on the mean nasalance scores for the speech stimuli. The song was left out of this analysis due to missing data from participant 7. There were significant main effects for condition [$F(3,12) = 9.36, p < 0.01$) and stimuli [$F(2,8) = 48.29, p < 0.01$). Fisher's LSD Multiple-Comparison post-hoc tests revealed that the nasalance scores for the forward voice focus condition (56.36%) were significantly higher than baseline 1 (50.04%), baseline 2 (44.8%) and the backward voice focus condition (42.71%). In addition, the nasalance scores in the backward voice focus condition also produced nasalance scores that were significantly lower than baseline 1 and the forward voice focus condition (all differences $p < 0.05$). The three stimuli all differed significantly from each other, with highest nasalance scores for the nasal stimulus, and lowest nasalance scores for the oral stimulus, as expected (all differences $p < 0.05$).

4. Discussion

The purpose of this study was to explore the immediate effects of forward and backward voice focus adjustments on the oral-nasal balance of children with hypernasality. The data were obtained from a convenience sample of seven children who were identified as eligible by their speech-language pathologist and who volunteered for the study. However, based on their baseline nasalance scores, participants 2 and 6 had nasalance scores for the oral stimulus within the normal range, indicating that they were not hypernasal. Both participants had repaired cleft palate, which may have led their speech-language pathologists to automatically recommend them for inclusion in the study. They were excluded from the data analysis presented in the results section. Inspection of their data in Table 2 demonstrates that their nasalance scores increased with forward focus and decreased with backward focus, as observed for typical speakers in previous research [47–49].

The first hypothesis stated that, in response to the forward voice focus adjustment (raised larynx and shortened vocal tract), participants' nasalance scores would increase. For the combined group of the five hypernasal speakers, forward voice focus resulted in considerable increases in nasalance of more than or equal to 10% during production of the oral stimulus. The results of the ANOVA also confirmed that the forward voice focus condition resulted in a significant increase in mean nasalance compared to baseline 1, the backward voice focus and baseline 2 conditions. Individually, forward voice focus resulted in an increase in nasalance during production of the oral stimulus (participant 1, participant 3, participant 5), nasal stimulus (participant 3), and phonetically balanced stimulus (participant 3). These results are similar to previous findings for typical speakers [47–49]. In contrast, participant 4 had a nasalance score for the nasal sentence that was 22% lower than baseline 1 in response to forward voice focus. In two previously described cases of a female hypernasal speaker [46] and a female typical speaker [49], lower nasalance scores were documented when speaking with a forward voice focus. It is possible that the forward voice focus condition may have led to a narrower velopharyngeal constriction for these speakers. Since variability of the individual morphology of the velopharyngeal sphincter seems to cause speakers to employ different velopharyngeal closure patterns [72,73], the effects of voice focus adjustments may also vary between individuals. Future work should include nasoendoscopic assessment or other imaging of the velopharyngeal sphincter.

The second hypothesis indicated that in response to the backward voice focus adjustment (lowered larynx and lengthened vocal tract), participants' nasalance scores would decrease. For the combined group of the five hypernasal speakers, backward voice focus resulted in a considerable decrease in nasalance during production of the nasal stimulus (−13% on average). The ANOVA results also revealed that the backward voice focus condition resulted in a decrease in nasalance compared to baseline 1 and the forward voice focus conditions. Individually, backward voice focus resulted in a decrease in nasalance during production of the oral stimulus (participant 4), nasal stimulus (participant 4 and participant 7), and phonetically balanced stimulus (participant 1). The results support previous findings [47–49].

Bell-Berti and Krakow [60] reported that longer vowel durations reduce the co-articulatory impact of adjacent consonants on velopharyngeal closure (i.e., the velum is in a stable raised position for longer). Since singing tasks generally prolong vowels, it was expected that the effects of the voice focus adjustments on the song would be more pronounced. Since there was missing data from participant 7 for the song, this stimulus was not included in the descriptive or inferential data analyses. However, the data in Table 2 still allow us to discuss individual participants. In the forward voice focus condition, all participants were found to increase their nasalance by 10% or more, similar to results reported in Santoni et al. [49]. In the backward voice focus condition, only participant 1's nasalance score dropped by −10%. Participants 4 and 5 had nasalance reductions of only −5%, and, intriguingly, participant 3's nasalance score increased by +26% in response to backward voice focus. While Peter, Abdul Rahman and Pillai [59] suggested that singing training could be a helpful behavioural intervention for reducing hypernasality, the small group of participants in the present study appeared to show more marked effects for the speech tasks than for the song.

On a group level, there were no significant differences between the first and second baselines. However, upon inspection of individual data, there were several individuals who had nasalance decreases of 10% or more by the final baseline, compared to the initial baseline. Such decreases were found for the oral stimulus (participant 1, participant 4 and participant 7), the nasal stimulus (participant 4), and the phonetically balanced stimulus (participant 1). On the other hand, a nasalance score increase of +11% during production of the phonetically balanced stimulus was noted for participant 7. In future research, the longer-term carryover effects of voice focus adjustments on oral-nasal balance should be investigated.

Since the present study was a first attempt to investigate the impact of voice focus on speakers with hypernasality, it is not possible to explain conclusively why and how the nasalance scores were affected. A number of different authors have advocated for oral sound redirection accomplished via increased mouth opening as a possible means to decrease hypernasality [38–42]. It could be argued that the effects observed in the present study could be completely explained by the changes to the relative impedance of the oral and nasal cavities achieved by differences in mouth opening between the forward and backward voice focus maneuver [34,35]. However, while there may have been a wider mouth opening in the backward focus condition, recent research by Alighieri and colleagues [74] found that nasalance scores decreased with increased mouth opening in normal subjects, but not in hypernasal speakers with cleft palate. The results for participant 4, who achieved lower nasalance scores in forward focus, are also difficult to explain as a result of reduced oral impedance. In future research, imaging techniques such as nasal endoscopy should be used to investigate if and how voice focus adjustments affect the configuration and movement of the velopharyngeal sphincter during speech.

Based on the results of the present study, it appears that voice focus adjustments may be helpful to reduce hypernasality for select patients. However, while the results of the present research are encouraging, it should be noted that speech therapy alone cannot remediate an anatomically insufficient velopharyngeal sphincter [1]. Voice focus adjustments as a therapeutic tool to address hypernasal speech probably have the greatest chance of success in patients with a physiologically adequate velopharyngeal mechanism. Although voice focus adjustments may have potential as a facilitative technique, extreme backward or forward voice foci are not socially desirable long-term speech qualities. After voice focus adjustments have been used to reduce hypernasality, the clinician would have to gradually phase out the extreme voice focus while maintaining the improved oral-nasal balance. If and how this can be accomplished should be investigated in further research.

The study had a number of limitations. The sample size was small. The convenience sampling approach resulted in a heterogeneous study group. Since this was a first evaluation of the effects of voice focus adjustments on speakers with hypernasality, it seemed reasonable to try it with a small number of participants. Participants 2 and 6 had to be excluded from the results because their nasalance scores for the oral stimulus were in the normal range, and participant 7's unwillingness to sing limited the statistical analysis of the song data. The effectiveness of the technique was only assessed with nasalance scores. Nasalance was considered the most reasonable measure for the purposes of the present study even though reported correlations between nasalance scores and nasality judgements have been variable [65,75–78]. Since listener assessments of hypernasal speech can be marred by low listener agreement [77], the added difficulty of assessing nasality in the presence of extreme voice focus adjustments would have added complexity to the listeners' task. Future research should include additional auditory-perceptual evaluations.

5. Conclusion

For the combined group of the five hypernasal speakers, forward voice focus resulted in higher, and backward focus resulted in lower nasalance scores. However, there was an exception: One male participant produced lower nasalance scores in the forward voice focus condition during production of the nasal stimulus. More research is needed to further investigate the potential of voice focus adjustments as a possible therapy technique for speakers with hypernasality. Future research should include nasopharyngoscopic or videofluoroscopic imaging to visualize the effect of voice focus adjustments on the velopharynx as well as auditory-perceptual assessments. The longer-term effectiveness of the intervention as a therapy technique should also be investigated.

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Declaration of competing interest

The authors have no conflicts of interest to declare.

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